

# Simulating Ganged SiPMs In The Photon Detectors

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William Kyle

# Motivation

- Each of the optical detectors contains 12 SiPMs
- Previously, optical simulations could only digitize data for each of the detector's 12 SiPMs onto one of the SSP's 12 channels
- Prices of the SSP's are much greater than the price of SiPMs
- Therefore, newer design proposals have suggested a more cost effective design where multiple SiPMs are ganged into each SSP channel
- So only need 1 SSP for every 3 Optical Detectors, rather than 1 SSP for every 12 SiPM Optical Detector
- Want to accommodate designs which gang 3 SiPMs onto each SSP channel in simulations

# Changes in the Simulation

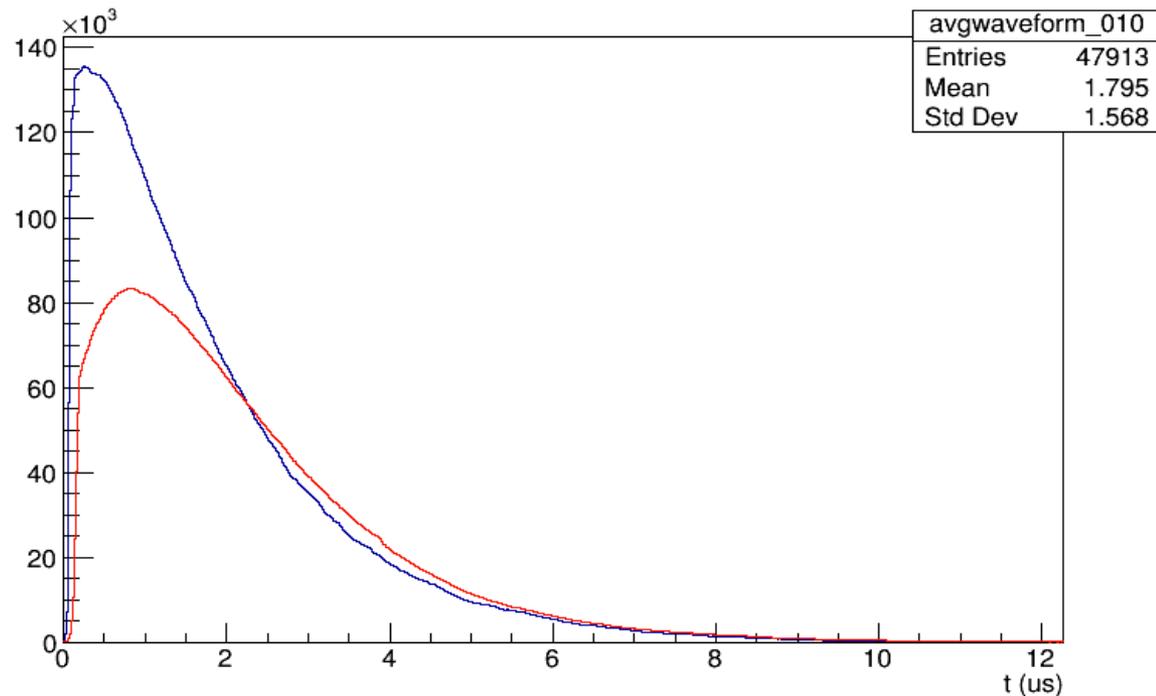
- Made the number of data channels for each Optical Detector into a FHiCL configurable parameter
  - `services.Geometry: @local::dune10kt_ganged_workspace_geo`
  - `services.PhotonVisibilityService: @local::dune10kt_workspace_photonvisibilityservice`
- These setups change the old 12 channels per detector to now have 4 channels per detector ( 3 SiPMs per channel )
  - `dune10kt_ganged_workspace_geo.SortingParameters.ChannelsPerOpDet: 4`
- This causes the amount of signal being read into each channel to be correct for a ganging of 3 SiPMs
- Also need to account for how the capacitance and response of the electronics in the detection systems change when ganged

# Changes in the Simulation

- Obtained new parameters for the SinglePEWaveform() pulses
  - Used reports which analyzed data signals taken from a test setup for ganging 3 SiPMs in conditions of the detectors
- Previous parameters
  - PulseLength: 4.0
  - PeakTime: 0.260
  - MaxAmplitude: 0.12
  - FrontTime: 0.009
  - BackTime: 0.476
- New parameters
  - dunefd\_opdigi\_threegang.PulseLength: 4.0
  - dunefd\_opdigi\_threegang.PeakTime: 0.260
  - dunefd\_opdigi\_threegang.MaxAmplitude: 0.062
  - dunefd\_opdigi\_threegang.FrontTime: 0.021
  - dunefd\_opdigi\_threegang.BackTime: 0.870

# Checking the Simulation

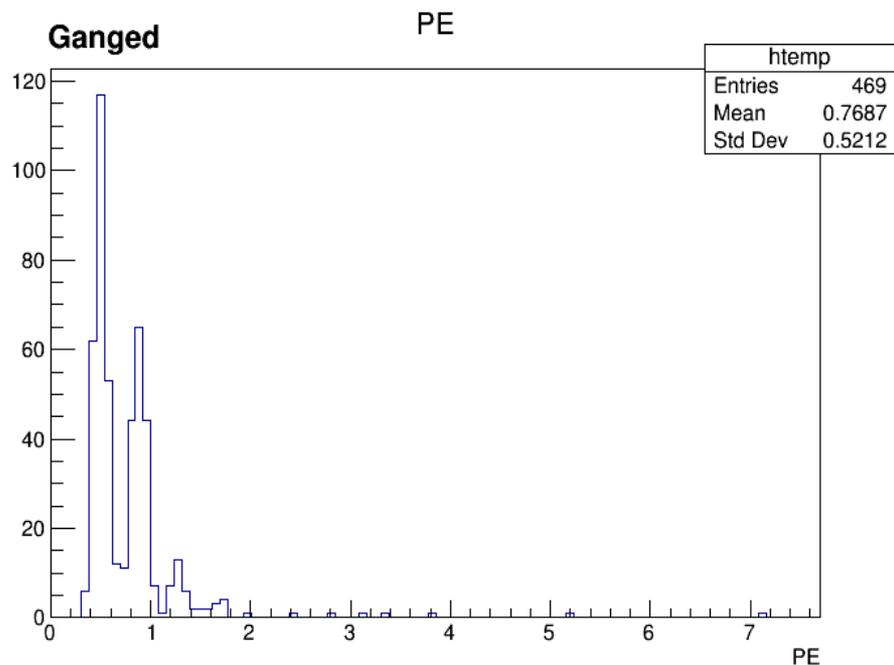
- Ran the same sim. through the unmodified and the modified digitization
- Check that waveforms are about half amplitude and about twice the time constant
- Averaging many waveforms shows that is the behavior seen



# Adjustments to Reconstruction

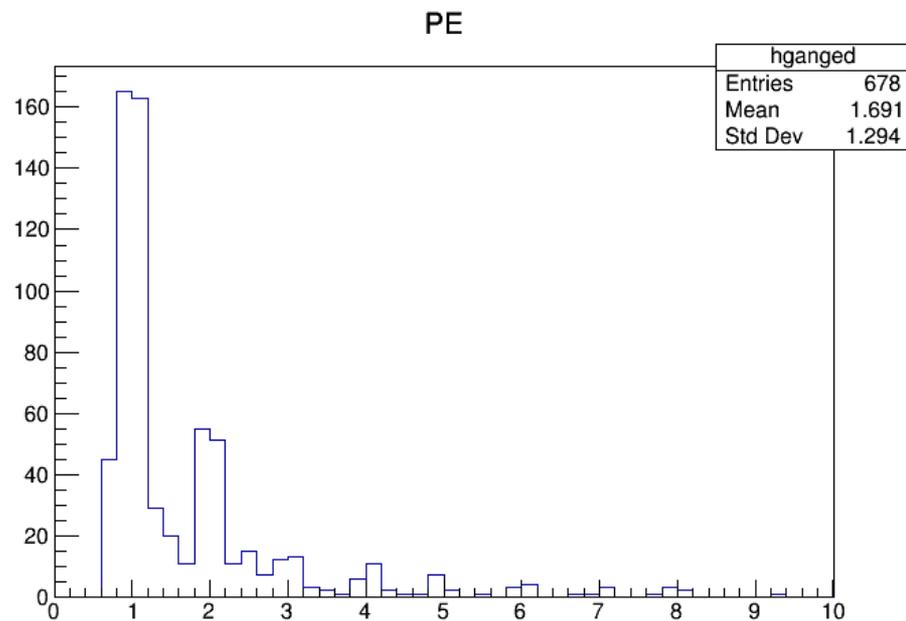
## Uncorrected OpHit Parameters

- `dunefd_ophit.SPEArea:` 1106
- `dunefd_ophit.SPEShift:` 0.304



## Corrected OpHit Parameters

- `dunefd_ophit_ganged:` @local::dunefd\_ophit
- `dunefd_ophit_ganged.SPEArea:` 1035
- `dunefd_ophit_ganged.SPEShift:` 0.603

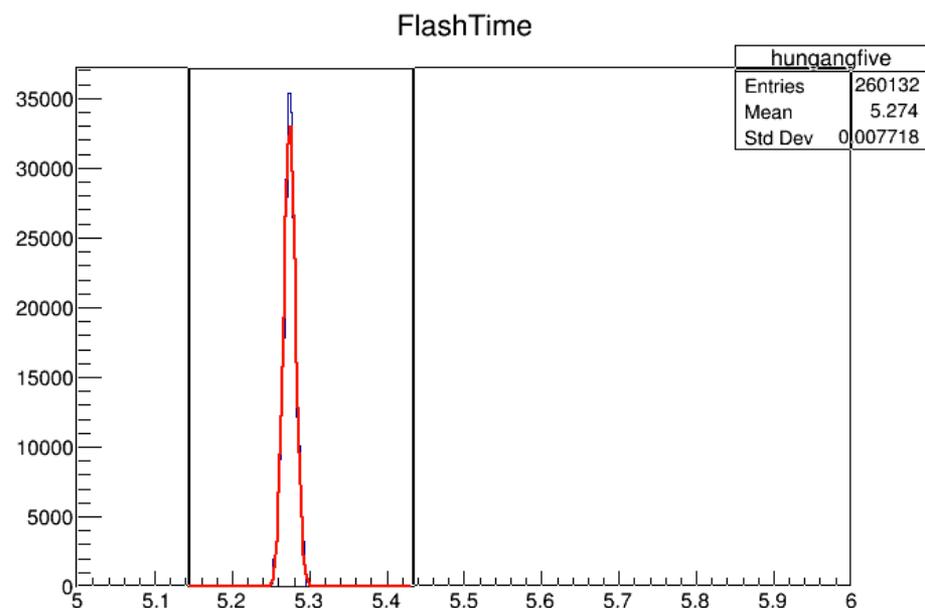


# Results for Ganged Timing Resolution

## Methods

- Generated large number of single event simulations at fixed location and time
- Compared reconstructed flash times for ganged and unganged reco.
- Also compared 10 MeV and 500 MeV electron events at 4 different event times

## Gaussian Fit



# Results for Ganged Timing Resolution

For 10 MeV electron events:

Unganged simulation and analyses:

Time Offset : 0.423583 us  $\pm$  0.0665455 us

**Width : 0.0665455 us**

Ganged simulation and analyses:

Time Offset : 0.371799 us  $\pm$  0.06226 us

**Width : 0.06226 us**

Unganged simulation, ganged analyses:

Time Offset : 0.372832 us  $\pm$  0.0593041 us

**Width : 0.0593041 us**

For 500 MeV electron events:

Unganged simulation and analyses:

Time Offset : 0.273916 us  $\pm$  0.00789436 us

**Width : 0.00789436 us**

Ganged simulation and analyses:

Time Offset : 0.196451 us  $\pm$  0.0165037 us

**Width : 0.0165037 us**

Unganged simulation, ganged analyses:

Time Offset : 0.195515 us  $\pm$  0.0177457 us

**Width : 0.0177457 us**

# Conclusions

- Implementing the ganging of 3 SiPMs onto each SSP Channel allows for more cost effective designs of the Optical Detection systems
- After making the necessary changes to the simulation, we were able to show that the new methods function as expected
- Using the new ganged simulation, we were able to test the resulting loss in timing resolution with ganged OpDets
- Found that for low energy events (10 MeV electrons), there is basically no change in timing resolution
  - All have std dev of about 60 ns
- For higher energy events, there is as loss in resolution, but change is small
  - Std dev goes from 7 ns to 17 ns
- This would indicate that ganging of SiPMs has a negligible enough affect on timing resolution to be viable for use in the photon detectors